# AN INTEGRATED MODEL FOR SUSTAINABLE SUPPLIER SELECTION AND MULTI-PERIOD MULTI-PRODUCT LOT-SIZING FOR PACKAGING FILM INDUSTRY IN IRAN

AMIR HOSSEIN AZADNIA

Universiti Teknologi Malaysia

# AN INTEGRATED MODEL FOR SUSTAINABLE SUPPLIER SELECTION AND MULTI-PERIOD MULTI-PRODUCT LOT-SIZING FOR PACKAGING FILM INDUSTRY IN IRAN

AMIR HOSSEIN AZADNIA

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Mechanical Engineering)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

MARCH 2014

Dedicated to:

The loving memory of my brother, Shahin.

My beloved family,
for their immeasurable support, encouragement, and love.

# ACKNOWLEDGEMENT

First and foremost, my unlimited and sincere appreciation goes to the Lord of the seven heavens and earth ALLAH (SWT) for His endless mercies, blessings and guidance through from birth till now and forever.

I would like to express my sincerest gratitude to my talented supervisor Associate Prof. Dr. Muhamad Zameri Mat Saman for his continuous guidance, support, and encouragement over past three years. His exceptional expertise and genuine concern regarding my progress and academic career is highly appreciated.

I would also like to thank my co supervisor, Associate Prof. Dr. Wong Kuan Yew for his kind guidance, patience, and motivation from the beginning to the end of this project.

And finally, warm thanks to the staff of Mechanical Engineering Faculty, Universiti Teknologi Malaysia for their help and support.

# ABSTRACT

The emergence of sustainability issues has created increasing interest among those involved in the field of sustainable supply chain management. Companies are motivated to modify their supply chains activities based on sustainability issues to enhance their overall level of sustainability in order to fulfil demanding environmental and social legislation and to deal with increasing market forces from different stakeholder groups. Within supply chain activities, selecting appropriate suppliers based on the criteria of sustainability, e.g., economic, environmental, and societal might help companies move towards sustainable development. Although several studies have been accomplished to incorporate sustainability criteria into supplier selection problem, little attention has been paid to developing a comprehensive mathematical model that allocates the exact quantities of orders to suppliers considering lot-sizing problems. Moreover, the effect of inflation as an important issue for companies in the developing countries has been neglected in studies that examined multi-period multi-product lot-sizing along with supplier selection. In this study, a multi-objective mathematical model for sustainable supplier selection integrated with multi-period multi-product lot-sizing problem under the effects of inflation was developed. The model consists of four objective functions which are minimizing total cost, maximizing total social, total environmental score, and total economic qualitative scores. The mathematical model was developed based on the parameters discovered by preprocessing the social, environmental, and economic data of suppliers using a rule-based-weighted fuzzy approach and fuzzy analytical hierarchy process. The model attempted to simultaneously balance different costs under inflationary conditions to optimize the total cost of purchasing and other objective functions. A comprehensive framework was developed as a road map for procurement organizations in order to facilitate the allocation of optimal order quantities to suppliers in a sustainable supply chain. The proficiency and applicability of a proposed approach was illustrated using a case study of packaging films from the food industry. For each main criterion of sustainability, their related subcriteria and influencing factors were extracted from literature and the most related ones were selected by company's experts. In this research, green competencies, environmental management system, pollution, occupational safety and health, training and education, contractual stakeholder, economic qualitative, and cost were selected by company's experts as the main subcriteria of sustainable supplier selection. The consideration of sustainability criteria in the proposed multi-objective model revealed that a higher value of sustainable purchasing can be achieved in comparison with a single objective cost-based model. In addition, the results show that the proposed model can provide a purchasing plan for the company while monitoring the effect of inflation and assuaging its concerns regarding sustainability issues.

# ABSTRAK

Kemunculan isu kelestarian, didapati telah mewujudkan peningkatan minat di kalangan mereka yang terlibat dalam bidang pengurusan rantaian bekalan yang lestari. Syarikat-syarikat terdorong untuk mengubah aktiviti rantaian bekalan mereka berdasarkan isu-isu kelestarian untuk meningkatkan keseluruhan tahap kemampanan untuk memenuhi undang-undang alam sekitar dan sosial serta bersaing dalam kuasa pasaran yang semakin meningkat daripada kumpulan-kumpulan berkepentingan yang berbeza. Dalam usaha membantu syarikat-syarikat untuk bergerak kearah pembangunan yang lebih mampan dalam aktiviti bekalan rantaian ini, pembekal yang sesuai harus dipilih berdasarkan aspek kriteria kelestarian seperti ekonomi, alam sekitar dan sosial. Walaupun, beberapa kajian telah dibuat untuk menggabungkan kriteria kelestarian di dalam masalah pemilihan pembekal, namun kurang tumpuan diberi terhadap pembangunan model matematik yang komprehensif untuk mempertimbangkan jumlah peruntukan sebenar di dalam usaha pembekalan dalam masalah 'lot-sizing' ini. Selain itu, isu penting seperti kesan inflasi di dalam syarikat-syarikat bagi negara membangun telah diabaikan dalam pelbagai kajian yang melibatkan pemilihan pembekal seperti produk pelbagai saiz. Dalam kajian ini, model matematik kepelbagaian-objektif untuk pemilihan pembekal yang mampan dengan pelbagai produk yang berbeza saiz dengan mengambil kira kesan inflasi telah dibangunkan. Model ini terdiri daripada empat objektif iaitu meminimumkan jumlah kos, memaksimumkan jumlah skor sosial, skor keseluruhan alam sekitar dan jumlah skor kualitatif ekonomi. Model matematik ini dibangunkan berdasarkan parameter yang dicapai melalui pra-pemprosesan data sosial, alam sekitar dan ekonomi pembekal, menggunakan kaedah *weighted fuzzy approach* dan kaedah *fuzzy analytical hierarchy process*. Model ini turut mengimbangi kos berbeza di bawah keadaan inflasi untuk mengoptimumkan jumlah kos pembelian dan fungsi objektif lain. Rangka kerja yang komprehensif turut dibangunkan sebagai panduan untuk kemudahan organisasi-organisasi dalam masalah kuantiti peruntukan yang optimum kepada pembekal dalam pengurusan rantaian bekalan yang mampan. Kajian kes terhadap pembungkusan filem dalam industri makanan dibuat bagi menggambarkan kecekapan dan kesesuaian pendekatan yang telah dicadangkan. Bagi setiap kriteria utama kelestarian, sub-kriteria yang berkaitan didapati daripada kajian literatur dan telah dipilih oleh pakar-pakar dalam syarikat. Dalam kajian ini, sub-kriteria yang telah dipilih untuk pemilihan pembekal yang mampan ialah kecekapan pengurusan hijau, sistem pengurusan alam sekitar, pencemaran, keselamatan dan kesihatan pekerjaan, latihan dan pendidikan, pemegang kepentingan kontrak, kualitatif ekonomi dan kos. Pertimbangan kriteria kelestarian yang dicadangkan ini menunjukkan bahawa nilai yang tinggi dalam pembelian yang mampan boleh dicapai berbanding dengan model *single-objective cost-based*. Di samping itu, keputusan menunjukkan bahawa model yang dicadangkan boleh menyediakan pelan pembelian untuk syarikat manakala pemantauan kesan inflasi boleh meredakan kebimbangan syarikat mengenai isu-isu kelestarian.

# TABLE OF CONTENTS


| CHAPTER | TITLE | | PAGE |
|---|---|---|---|
| | **DECLARATION** | | ii |
| | **DEDICATION** | | iii |
| | **ACKNOWLEDGMENTS** | | iv |
| | **ABSTRACT** | | v |
| | **ABSTRAK** | | vi |
| | **TABLE OF CONTENTS** | | vii |
| | **LIST OF TABLE** | | xi |
| | **LIST OF FIGURES** | | xiv |
| | **LIST OF SYMBOLS** | | xv |
| | **LIST OF ABBREVIATIONS** | | xvi |
| | **LIST OF APPENDICES** | | xviii |
| **1** | **INTRODUCTION** | | **1** |
| | 1.1 | Background of the Project | 1 |
| | 1.2 | Problem Statement | 6 |
| | 1.3 | Research Questions | 7 |
| | 1.4 | Objectives and Scope of Study | 7 |
| | 1.5 | Significance of Study | 8 |
| | 1.6 | Structure of Thesis | 9 |
| | 1.7 | Summary | 10 |
| **2** | **LITERATURE REVIEW** | | **11** |
| | 2.1 | Overview | 11 |

| | | | |
|---|---|---|---|
| | 2.2 | Supplier Selection and Order Allocation | 11 |
| | 2.3 | Order Lot-sizing Integrated with Supplier Selection | 14 |
| | 2.4 | Inventory Lot-sizing and Inflation Rate | 22 |
| | 2.5 | Sustainability | 23 |
| | 2.6 | Sustainable Supply Chain Management | 25 |
| | 2.7 | Sustainable Supplier Selection | 28 |
| | | 2.7.1 Economic and Environmental Criteria | 29 |
| | | 2.7.2 Social Criteria | 40 |
| | 2.8 | Introduction to Fuzzy Logic | 48 |
| | | 2.8.1 Fuzzy Inference System | 50 |
| | | 2.8.2 Why Fuzzy logic For Sustainable Supplier Assessment? | 52 |
| | | 2.8.3 Fuzzy Analytic Hierarchy Process | 54 |
| | 2.9 | Summary | 55 |
| **3** | **METHODOLOGY** | | **57** |
| | 3.1 | Overview | 57 |
| | 3.2 | Research Methodology | 57 |
| | 3.3 | Research Framework | 60 |
| | | 3.3.1 Selecting Products and Their Corresponded Suppliers | 62 |
| | | 3.3.2 Selecting Appropriate Criteria to Evaluate Suppliers | 62 |
| | | 3.3.3 Suppliers' Social and Environmental Assessment | 63 |
| | | 3.3.4 Assessing the Suppliers Regarding the Economical Qualitative Criteria | 69 |
| | | 3.3.5 Developing Multi-objective Mathematical Programming Model | 70 |
| | 3.3 | Summary | 71 |
| **4** | **MODEL DEVELOPEMENT** | | **72** |
| | 4.1 | Overview | 72 |

| | | | |
|---|---|---|---|
| | 4.2 | Model Formulation | 72 |
| | | 4.2.1 Notations | 73 |
| | | 4.2.2 Objective Functions | 74 |
| | | 4.2.2.1 Total cost Objective Function | 74 |
| | | 4.2.2.2 Total Economical Qualitative Score | 79 |
| | | 4.2.2.3 Total Environmental Score | 80 |
| | | 4.2.2.4 Total Social Score | 80 |
| | | 4.2.3 Constraints | 81 |
| | | 4.2.3.1 Demand Constraint | 81 |
| | | 4.2.3.2 Capacity Constraint | 81 |
| | | 4.2.3.3 Charging Ordering Cost Constraint | 82 |
| | | 4.2.3.4 Storage Capacity Constraint | 82 |
| | | 4.2.3.5 End of Horizon Inventory Level Constraint | 83 |
| | | 4.2.3.6 Binary and non-negativity constraints | 83 |
| | 4.3 | Different Optimization Approaches | 85 |
| | | 4.3.1 Weighted Sum Approach | 86 |
| | | 4.3.2 Fuzzy Weighted Max-min Approach | 86 |
| | | 4.3.3 Additive Weighted Approach | 90 |
| | 4.4 | Summary | 91 |
| **5** | **CASE STUDY, RESULTS AND DISCUSSION** | | **92** |
| | 5.1 | Overview | 92 |
| | 5.2 | Case Study | 93 |
| | 5.3 | Criteria Definition and Selection | 96 |
| | 5.4 | Weighted Fuzzy Approach for Supplier Social and Environmental Evaluation | 102 |
| | | 5.4.1 Determining Social and Environmental Sub criteria Weights | 102 |
| | | 5.4.2 Data Collection | 106 |
| | | 5.4.2.1 Work Safety and Labor Health | 106 |
| | | 5.4.2.2 Training, Education, and Community Development | 107 |

5.4.2.3 Contractual Stakeholder Influence 108
5.4.2.4 Environmental Management System 109
5.4.2.5 Pollution 110
5.4.2.6 Green Competencies 112
5.4.3 Fuzzy Inference System 113
5.5 Determining Supplier Scores for Economic Qualitative Criteria 117
5.6 Supplier Evaluation Summary 121
5.7 Developing a Graphical User Interface for Sustainable Supplier Selection 123
5.8 Order Allocation 126
5.8.1 Model Validation 129
5.8.2 Model Optimization 136
5.8.2.1 Order Allocation Using a Weighted Sum Approach (WSA) 136
5.8.2.2 Order Allocation Using Fuzzy Weighted Max-min Approach (FWM) 138
5.8.2.3 Order Allocation using Fuzzy Additive Weighted Approach (FAW) 141
5.8.3 Comparisons and Sensitivity Analysis 144
5.9 Managerial Implications 148
5.10 Advantages of Proposed Model 152
5.11 Summary 153

**6 CONCLUSIONS 154**

6.1 Concluding Remarks 154
6.1 Recommendations for Future research 157

**REFERENCES 158**

Appendices A-J 171-210

# LIST OF TABLES


| TABLE NO. | TITLE | PAGE |
|---|---|---|
| 2.1 | Multi-period lot-sizing with supplier selection models | 19 |
| 2.2 | Economic criteria for supplier selection | 31 |
| 2.3 | Environmental sustainability criteria | 37 |
| 2.4 | Social sustainability criteria | 43 |
| 2.5 | Sustainable/Green supplier selection approaches | 45 |
| 3.1 | Fuzzy numbers and linguistic variables | 64 |
| 5.1 | Demands | 96 |
| 5.2 | Selected environmental and social criteria | 98 |
| 5.3 | Fuzzy numbers and linguistic variables | 103 |
| 5.4 | Pairwise comparison for social sub criteria | 103 |
| 5.5 | Pairwise comparison for environmental sub criteria | 103 |
| 5.6 | Sub criteria weights | 105 |
| 5.7 | Ranking order of OHSMS | 106 |
| 5.8 | Suppliers' scores in WS | 107 |
| 5.9 | Training, education, and community development | 108 |
| 5.10 | Ranking orders for ID and SE | 109 |
| 5.11 | Suppliers' scores in CS | 109 |
| 5.12 | Ranking orders for EMC and MEC | 110 |
| 5.13 | Suppliers' scores in EMS | 110 |
| 5.14 | Ranking orders for PC | 111 |
| 5.15 | Suppliers' scores in PO | 111 |
| 5.16 | Ranking for EC and RC | 112 |
| 5.17 | Supplier EC and RC scores | 113 |
| 5.18 | Fuzzified input variables | 114 |

| | | |
|---|---|---|
| 5.19 | Number of rules for the sub criteria | 115 |
| 5. 20 | Fuzzy rules samples | 116 |
| 5.21 | Suppliers scores for environmental criterion | 116 |
| 5.22 | Suppliers scores for social criterion | 117 |
| 5.23 | Sub criteria pairwise comparisons with respect to the main objective | 118 |
| 5.24 | Economic qualitative sub criteria weight | 119 |
| 5.25 | Sub criteria pairwise comparisons with respect to quality | 119 |
| 5.26 | Suppliers pairwise comparisons with respect to loyalty | 119 |
| 5.27 | Suppliers pairwise comparisons with respect to delivery | 120 |
| 5.28 | Suppliers pairwise comparisons with respect to technical capability | 120 |
| 5.29 | Suppliers importance weighs in each sub criterion | 120 |
| 5.30 | Suppliers scores in economic qualitative criterion | 121 |
| 5.31 | Suppliers score in sustainability criteria | 121 |
| 5.32 | Supplier/product data 1 | 127 |
| 5.33 | Supplier/product data 2 | 127 |
| 5.34 | Holding cost and needed space for each kg of product | 127 |
| 5.35 | Model's parameters values | 127 |
| 5.36 | Objective functions pairwise comparisons | 128 |
| 5.37 | Objective functions weights | 128 |
| 5.38 | Demands for validation process (kg/t) | 129 |
| 5.39 | Parameters for the validation process | 129 |
| 5.40 | Holding cost and needed space for each kg of product | 130 |
| 5.41 | Results of optimization of each objective function in validation process | 131 |
| 5.42 | Optimizing cost objective function without inflation | 133 |
| 5.43 | Negative and positive Ideal solutions | 134 |
| 5.44 | Results of multi-objective optimization | 135 |
| 5.45 | Negative and positive Ideal solutions | 136 |
| 5.46 | Order allocation using WSA | 138 |
| 5.47 | The objective functions values based on WSA | 138 |
| 5.48 | Ideal positive and negative solutions | 139 |
| 5.49 | Order allocation using fuzzy weighted max-min approach | 141 |

| | | |
|---|---|---|
| 5.50 | The objective functions values based on weighted max-min approach | 141 |
| 5.51 | Order allocation using fuzzy weighted max-min approach | 143 |
| 5.52 | The objective functions values based on weighted max-min approach | 143 |
| 5.53 | Comparison of the solution approaches | 145 |
| 5.54 | Comparison of the solution approaches single and multi-objective | 145 |
| 5.55 | Normalized sustainability sub criteria values for suppliers | 149 |

# LIST OF FIGURES


| FIGURE NO. | TITLE | PAGE |
|---|---|---|
| 2.1 | Triple bottom line | 24 |
| 2.2 | House of Sustainable supply chain management | 26 |
| 2.3 | Sustainable supply chain management | 27 |
| 2.4 | Triangular fuzzy number | 49 |
| 1.5 | Fuzzy inference system | 50 |
| 2.6 | Fuzzy inference engine | 51 |
| 3.1 | Research methodology process | 58 |
| 3.2 | Research Framework | 61 |
| 3.3 | Weighted Fuzzy Approach | 63 |
| 3.4 | Fuzzy triangular membership functions | 67 |
| 5.1 | Company's production line | 95 |
| 5.2 | Company's warehouse | 95 |
| 5.3 | Selected criteria, sub criteria, and influencing factors | 101 |
| 5.4 | Hierarchy structure | 117 |
| 5.5 | Suppliers' final scores for each sustainability dimenstion | 122 |
| 5.6 | Graphical user interface flowchart | 124 |
| 5.7 | Order allocations for product 2 | 133 |
| 5.8 | Order allocations for Product 1 | 133 |
| 5.9 | Order using single-objective and multi-objective models | 146 |
| 5.10 | Order allocations to supplier with and without considering inflation | 147 |
| 5.11 | Volume of purchases for each period with and without considering inflation | 147 |
| 5.12 | Suppliers' sub criteria scores | 149 |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| $C_{ij}$ | - | Available capacity of supplier *j* for product *i* |
| $D_{it}$ | - | Demand of product *i* at time *t* |
| $E_{ij}$ | - | Score of supplier *j* for product *i* in environmental criteria achieved through weighted fuzzy approach |
| $H_{it}$ | - | Holding cost of product *i* at time *t* |
| $I$ | - | Number of products; |
| $J$ | - | Number of suppliers |
| $O_{jt}$ | - | Ordering cost of supplier *j* at time t |
| $P_{ijt}$ | - | Price of product *i* from supplier *j* at time *t* |
| $\varphi_{jt}$ | - | Transportation cost from supplier *j* per kg at time *t* |
| $r$ | - | Inflation rate |
| $R$ | - | Effective inflation rate (*r*-z) |
| $S$ | - | Maximum storage space |
| $T$ | - | Number of periods |
| $\tau_{ij}$ | - | Score of supplier *j* for product *i* in social criteria achieved through weighted fuzzy approach |
| $V_i$ | - | Storage space needed for product *i* |
| $\omega_{ij}$ | - | Score of supplier *j* for product *i* in economic qualitative criteria achieved through FAHP |
| $x_{ijt}$ | - | Number of product *i* purchased from supplier *j* at time *t* |
| $Y_{jt}$ | - | Binary variable: 1, if an order allocated to supplier *j* at time *t*, otherwise, 0 |
| z | - | Discount rate |

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| AHP | - | Analytic Hierarchy Process |
| ANP | - | Analytic Network Processes |
| CEO | - | Chief Executive Officer |
| COA | - | Centroid of Area |
| CS | - | Contractual Stakeholder |
| DEA | - | Data Envelopment Analysis |
| EC | - | Energy Consumption Control |
| ELECTRE | - | Elimination and Choice Expressing Reality |
| EMC | - | Environmental Management Certificates |
| EMS | - | Environmental Management System |
| EOQ | - | Economic Order Quantity |
| FA | - | Fuzzy Approach |
| FAHP | - | Fuzzy Analytic Hierarchy Process |
| FAW | - | Fuzzy Additive Weighted Approach |
| FIS | - | Fuzzy Inference System |
| FWM | - | Fuzzy Weighted Max-min Approach |
| GAMS | - | General Algebraic Modeling System |
| GC | - | Green Competencies |
| GD | - | Grant and Donation |
| GP | - | Goal Programming |
| HSI | - | Health and Safety Incident |
| ID | - | Information Disclosure |
| MADM | - | Multi-attribiute Decision-Making |
| MATLAB | - | Matrix Laboratory |
| MCDM | - | Multi-criteria Decision-Making |
| MEC | - | Management's commitment to the environment and Support |

| | | |
|---|---|---|
| MINLP | - | Mixed Integer Non-linear Programming |
| MIP | - | Mixed Integer Programming |
| MODM | - | Multi-objective Decision-Making |
| MOP | - | Multiple-objective Programming |
| NN | - | Neural Network |
| OHSMS | - | Occupational Health and Safety Management System |
| PC | - | Pollution Control Capability |
| PEHS | - | Personnel Engagement in Health and Safety Committee |
| PO | - | Pollution |
| PW | - | Product Waste |
| RC | - | Recycling Capabilities |
| SCM | - | Supply Chain Management |
| SSA | - | Scatter Search Algorithm |
| SE | - | Stakeholder Engagement |
| SSCM | - | Sustainable Supply Chain Management |
| TBL | - | Triple Bottom line |
| TE | - | Training Education and Community Development |
| TOPSIS | - | Techniques for Order Preference by Similarity to Ideal Solution |
| TVSP | - | Total Value of Sustainable Purchasing |
| WFA | - | Weighted Fuzzy Approach |
| WS | - | Worker Safety and Labor Health |
| WSA | - | Weighted Sum Approach |

# LIST OF APPENDICES


| APPENDIX | TITLE | PAGE |
|---|---|---|
| A | Company's Experts Specifications | 171 |
| B | Adjustment Mechanism | 172 |
| C | Questionnaire for Determining Environmental and Social Subcriteria Weights | 174 |
| D | Constructed Fuzzy Rules | 176 |
| E | Questionnaire for Evaluating the Suppliers Based on Economic Qualitative Subcriteria | 181 |
| F | Graphical User Interface | 184 |
| G | Questionnaire for Determining Objective Functions Weights | 187 |
| H | GAMS& LINGO Codes for Validation | 189 |
| I | Codes in LINGO for Multi-Objective Model | 199 |
| J | Publications | 209 |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Project

Supply chain management (SCM) includes the requirements to provide a well-organized supply process by continuous monitoring and controlling the process in order to guarantee that customers and organizational needs are met. In order to have an efficient SCM, good coordination must be established between all components of the supply chain.

An important concern in SCM is supplier selection. As organizations become more dependent on their suppliers, the direct and indirect consequences of poor decisions become more severe (De Boer *et al*., 2001). Moreover, it is needed for companies to develop effective procurement strategies in order to reduce costs, obtain higher quality goods, and achieve shorter lead times to ensure their survival in a competitive global market (Ebrahim *et al*., 2009). Therefore, the selection of suppliers has grown in importance as a strategic issue in the area of SCM. Che and Wang (2010) stated that companies should make important decisions regarding the evaluation and selection of their suppliers in order to collaborate with qualified suppliers and eliminate unqualified ones.

Building long-term relationships with qualified suppliers can lead to a rapid exchange of information which can support SCM. Seuring and Müller (2008) defined supplier selection as the process in which suppliers are reviewed, evaluated, and chosen to become a part of the organization's supply chain. This area of research has been significantly studied and is of extreme importance, especially in the companies where procurement has a significant effect on profits (Ghodsypour and O'Brien, 1998; Amin *et al*., 2011; Lima Junior *et al*., 2013). Therefore, a comprehensive decision tool is very much required for these companies in order to maintain their competitive advantages in the wake of growing competition.

Several criteria such as cost, quality, lead times, capacity, technical potential, design performance, and environmental performance affect a supplier's performance. A list of 23 criteria was identified for supplier evaluation and selection in a study conducted by Dickson (1966). In another study, Weber *et al*. (1991) identified that decisions to select suppliers are influenced by key factors. These key factors were derived from reviewing 74 related papers that appeared after Dickson's (1966) distinguished research work. According to Weber *et al*. (1991) review, in the area of supplier selection it was found that price, quality and delivery performance are the most important factors that must be considered when selecting a supplier. In other words, supplier selection is a multiple-criteria decision making (MCDM) that requires a tradeoff between conflicting quantitative and qualitative criteria to select the best suppliers (Ebrahim *et al*., 2009).

According to the studies in the literature, the perception is that there are three important decisions that are related to supplier selection. These three decisions are concerned with the kind of products to be ordered, the quantities required, and when they are required (Aissaoui *et al*., 2007; Hassini, 2008; Woarawichai *et al*., 2011). These three decisions make order lot-sizing and supplier selection closely related. Lot-sizing problems, as one of the most important issues facing SCM, are categorized as production planning problems because they contain the objective of determining when an order should take place and the quantities to be ordered in order

to satisfy demand while minimizing costs such as purchasing and inventory costs (Woarawichai *et al*., 2011).

The idea of lot-sizing was developed by Wagner and Whitin (1958). Their published paper has been elected as one of the most influential publications in Management Science, which shows the significance of lot-sizing problems in the field of SCM (Wagner, 2004). The integration of lot-sizing models and supplier selection has recently attracted the attention of scholars and practitioners. Several studies in this field (Basnet and Leung, 2005; Aissaoui *et al*., 2007; Dai and Qi, 2007; Hassini, 2008; Ustun and Demirtas, 2008; Ebrahim *et al*., 2009; Keskin *et al*., 2010; Rezaei and Davoodi, 2011a; Sawik, 2011; Woarawichai *et al*., 2011; Hammami *et al*., 2012; Rezaei and Salimi, 2012) examined situations in which buyers needed to determine the optimal quantity of a product to order in each period from each supplier to meet the requirements of a production plan while satisfying given constraints. In these studies, some objective functions such as total cost (purchasing, inventory, ordering, and transportation), quality, and service levels were formulated.

Incorporating the decision to schedule orders over time with vendor selection may significantly reduce costs over the planning horizon. In a situation where a multi-period horizon is defined, the orders can be allocated to one or more suppliers for each period. Moreover, buyers can buy products early in the planning horizon and keep them as inventory until they are needed in the future while holding costs are taken into account.

In the real world applications, although order allocation becomes more complicated in the presence of a multi-period planning horizon, there can be potential opportunities for buyers to create more effective purchasing plans by incorporating inventory management systems. Multi-period lot-sizing integrated with supplier selection can provide a balance between inventory costs and allow suppliers with lower costs to be selected (Aissaoui *et al*., 2007).

One of the critical factors that can affect a buyer's decisions and the lot-size of each product is the inflation rate. The effect of inflation has become a constant characteristic and a very important issue in several developing economies, especially in the third world countries (Onawumi *et al*., 2011). Considering the effect of inflation on lot-sizing can reduce the total cost of purchasing over the planning horizon. Since the inflation rate leads to an increase in products prices, it can harm companies that do not consider this issue in their purchasing and inventory control functions. There are a few studies in the existing literature that considered the effect of the inflation rate on inventory control (De and Goswami, 2006; Sana, 2008; Sana and Chaudhuri, 2008). However, there are very limited studies in the literature that considered the effect of the inflation rate on inventory lot-sizing integrated with supplier selection even though it should be considered when addressing purchasing and logistic issues.

On a different note, the emergence of sustainability over the past few decades has witnessed increasing interest from practitioners and academia in the field of sustainable SCM. Companies have been motivated to modify their supply chains activities based on sustainability issues to enhance their overall level of sustainability in order to fulfil more demanding environmental and social legislation and to deal with increasing market forces from different stakeholder groups.

Traditionally, the process of supplier selection was influenced by different intangible and tangible criteria such as price, quality, technical capability, and delivery performance (Önüt *et al*., 2009; Friedl and Wagner, 2011). Further studies show that cooperation with environmentally, socially, and economically potent suppliers can improve supply chain sustainability and positively impact sustainable development (Büyüközkan and Çifçi, 2011). Therefore, many organizations have begun to focus on incorporating environmental, social, and economic aspects of sustainability in their supplier selection processes by adapting sustainable supply chain initiatives (Seuring and Müller, 2008; Govindan *et al*., 2013).

Sustainable supplier selection can be defined as a classical supplier selection in which environmental and social criteria are used to evaluate, select, and monitor the performance of suppliers (Genovese *et al*., 2010). Most studies in this field have only focused on the economic and environmental aspects of sustainability (Shen *et al*.2012; Handfield *et al*., 2002; Lu *et al*., 2007; Kannan *et al*., 2008; Hsu and Hu, 2009; Kannan *et al*., 2009; Lee *et al*., 2009; Yeh and Chuang, 2011; Büyüközkan and Çifçi, 2012; Shaw *et al*., 2012). More recently, few researchers have attempted to investigate the social facet of sustainability either separately or together with economic and environmental aspects when considering the of supplier selection. In addition, several companies in the world have tried to incorporate sustainability issues on their supplier selection process. Wallmart has recently provided a sustainable supplier assessment system that encompasses several questions for assessing suppliers in different categories such as nature and resource, material efficiency, energy and climate, and community influence. The BMW group implemented a supplier evaluation considering some issues such as resource management and environmental protection, and social responsibility. Toyota Motor Corporation considers corporate social responsibility issues in their supplier selection and evaluation system. However, there is still no comprehensive model or framework for supplier selection and order allocation that simultaneously considers all three aspects of sustainability while the effect of inflation is taken into account.

Nowadays, packaging films are massively used in food industries. Considering the high demand rate of packaging films in food manufacturing companies over a planning horizon, providing a comprehensive mathematical model for sustainable supplier selection and order allocation can help companies achieve higher value of sustainable purchasing. Therefore, there is a need for food manufacturing companies to implement a systematic procurement method to address the abovementioned issues in order to move towards sustainable development. Hence, this study aims at developing a multi-objective mathematical programming in order to facilitate the process of decision-making.

In this study, a comprehensive framework was developed associated with sustainable supplier selection integrated with multi-period multi-product inventory lot-sizing. The main aim of this study is to deal with sustainable supplier selection integrated with multi-period multi-product inventory lot-sizing in the presence of increasing inflation. This study attempts to determine the quantities of product to be ordered for certain periods from various suppliers while ensuring that all of the system's constraints and needs are satisfied. A multi-objective programming model is developed that considers inflation rates and additional criteria for sustainable issues that are different from traditional criteria (cost, quality, and delivery). In order to solve multi-objective models, different approaches are utilized. MATLAB, LINGO, and GAMS software are used to analyze the data.

## 1.2 Problem Statement

The traditional supplier selection approach was demonstrated to be competitive and practical until the emergence of sustainability issues, which has drawn the attention of managers and CEOs who wish to incorporate sustainability in all aspects of their manufacturing and supply chain activities. Companies understand that in order to provide sustainable products and services for today's competitive markets, they must improve the sustainability degree of their supply chains. Suppliers are an important part of the supply chain and they can affect the sustainability of the supply chain. As a result, it has become necessary to select and evaluate suppliers based on sustainability criteria. So far, only few studies have been conducted that consider the economic, environmental, and social criteria for supplier selection. It can be perceived that the focus on sustainability issues and how they apply to supplier selection and order allocation in practice is at an early stage.

Although many studies have been conducted that looked at multi-period multi-product order lot-sizing together with supplier selection (Rezaei and Davoudi

2008, 2011b), there is not any research that considers the effect of inflation, especially in developing countries, on these issues. Furthermore, far too little attention has been paid to developing comprehensive frameworks and practical mathematical models for order allocation that consider sustainability issues in the integrated problem of supplier selection and multi-period multi-product lot-sizing. Consequently, this study has been carried out in order to address these oversights.

## 1.3 Research Questions

The main questions asked in this study are:

i. What are the appropriate sustainable criteria to use to evaluate suppliers?
ii. What is the weight of each criterion used to evaluate suppliers?
iii. How can the effects of inflation on supplier selection with multi-period multi product inventory lot sizing be formulated?
iv. What are the objective functions and constrains of a multi-objective mathematical model that considers sustainability criteria beside the traditional criteria used to select suppliers while considering inventory lot-sizing and increasing inflation?
v. What is the optimum order quantity that can be allocated to each supplier for each period for each product?

## 1.4 Objectives and Scope of Study

The main objectives of this study are as follows:

i. To develop a comprehensive framework for sustainable supplier selection.

ii. To develop an integrated multi-objective model for sustainable supplier selection and multi period multi-product inventory lot sizing that considers the effects of inflation.
iii. To validate the developed multi-objective mathematical model by a case study and optimize it in order to determine the optimum order quantities of products that can be allocated to suppliers in each period in the integrated problem of sustainable supplier selection and multi-period multi-product inventory lot-sizing.

The scope of the research includes:

i. A case study of packaging film for the food industry in Iran was selected.
ii. Three kinds of packaging films with their related suppliers were selected.
iii. MATLAB, LINGO, GAMS, and Excel software were used to analyze the data.

## 1.5 Significance of Study

Within sustainability practices, incorporating sustainability issues into organizational procurement decisions has become an important issue. Although some industries use supplier selection systems, there is an opportunity to develop a comprehensive framework and a mathematical model that would facilitate the selection of sustainable suppliers and order allocation. Subsequently, this would help companies select their suppliers and allocate orders to them in a systematic manner. Therefore, this study attempts to address these issues by developing a comprehensive framework and a mathematical model. Moreover, the effect inflation rate is taken into account in the development of the mathematical model. Due to high inflation rate in the developing countries, especially third world countries, it is very important

to consider the effect of inflation rate on their inventory management and purchasing activities in order to minimize the risk of losing profit. Considering prices under inflationary conditions along with ordering, holding, and transportation costs in the cost objective function of the mathematical model for sustainable supplier selection and order lot-sizing will help decision makers to achieve the best procurement plan and reduce their total costs when dealing with planning horizons. The mathematical model can make balance between these factors in the presence of inflation rate in order to achieve the best procurement plan over a planning horizon. Developing a comprehensive framework as a decision support system for sustainable supplier selection integrated with-lot sizing can facilitate the process of supplier selection and order allocation for companies and their managers and help them compete in the global market while improving their sustainability. The framework can be used as a road map to show how sustainable supplier selection and multi-period-multi-product lot-sizing can be integrated together. Hence, this study aims at developing a multi-objective mathematical programming and a comprehensive framework in order to facilitate the process of decision-making.

## 1.6 Structure of Thesis

This report consists of six chapters, summarized as follow: Chapter 1 is the introduction of the study. This chapter explains the research questions, problem statement, objectives of the study, the scope of the study, and matters that were related to the introduction of project. Chapter 2 belongs to the literature review and contains several topics related to this study. This chapter also provides definitions, principles, and approaches that were used while conducting this project. Chapter 3 discusses the methodology of the research, research framework and provides a detailed explanation of its components. Chapter 4 encompasses model formulation and development. This chapter also provides a detailed explanation of different optimization approaches. Chapter 5 presents the case study, results, and discussions of this project. Chapter 6 provides the final conclusions and gives a brief summary of the study and recommendations for future works.

## 1.7 Summary

This chapter has given a general introduction to the entire study. At the beginning of this chapter, the introduction of supplier selection and lot-sizing were briefly discussed. Then, sustainability issues and their importance in SCM were explained. This was followed by the research statement and the issues that face this area of study. The objectives and scope of the project were stated to define the boundaries of the study. The significance of the study was discussed. Lastly, the arrangement of the entire report was explained.

## REFERENCES


Aissaoui, N., M. Haouari and E. Hassini (2007). Supplier selection and order lot sizing modeling: A review. *Computers & Operations Research* 34(12): 3516-3540.

Akman, G. and H. Pışkın (2013). Evaluating Green Performance of Suppliers via Analytic Network Process and TOPSIS. *Journal of Industrial Engineering* 2013.

Amelia, L., D. A. Wahab and A. Hassan (2009). Modelling of palm oil production using fuzzy expert system. *Expert Systems with Applications* 36(5): 8735-8749.

Amin, S. H., J. Razmi and G. Zhang (2011). Supplier selection and order allocation based on fuzzy SWOT analysis and fuzzy linear programming. *Expert Systems with Applications* 38(1): 334-342.

Amindoust, A., S. Ahmed, A. Saghafinia and A. Bahreininejad (2012). Sustainable supplier selection: A ranking model based on fuzzy inference system. *Applied Soft Computing* 12(6): 1668-1677.

Awasthi, A., S. S. Chauhan and S. K. Goyal (2010). A fuzzy multicriteria approach for evaluating environmental performance of suppliers. *International Journal of Production Economics* 126(2): 370-378.

Bai, C. and J. Sarkis (2010a). Green supplier development: analytical evaluation using rough set theory. *Journal of Cleaner Production* 18(12): 1200-1210.

Bai, C. and J. Sarkis (2010b). Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics* 124(1): 252-264.

Baskaran, V., S. Nachiappan and S. Rahman (2012). Indian textile suppliers' sustainability evaluation using the grey approach. *International Journal of Production Economics* 135(2): 647-658.

Basnet, C. and J. M. Leung (2005). Inventory lot-sizing with supplier selection. *Computers & Operations Research* 32(1): 1-14.

Bayrak, M. Y., N. Çelebi and H. Taşkin (2007). A fuzzy approach method for supplier selection. *Production Planning & Control* 18(1): 54-63.

Ben-Daya, M., M. Darwish and K. Ertogral (2008). The joint economic lot sizing problem: Review and extensions. *European Journal of Operational Research* 185(2): 726-742.

Bruntdland Commission Report (1987) . Our Common Future: From One Earth to One World,. Oxford University Press, *World Commission on Environment and Development*, vol. IV: 22-23.

Buckley, J. (1985). Ranking alternatives using fuzzy numbers. *Fuzzy sets and systems* 15(1): 21-31.

Buffa, F. P. and W. M. Jackson (1983). A goal programming model for purchase planning. *Journal of Purchasing and Materials Management* 19(3): 27-34.

Büyüközkan, G. and G. Çifçi (2011). A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information. *Computers in Industry* 62(2): 164-174.

Büyüközkan, G. and G. Çifçi (2012). A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers. *Expert Systems with Applications* 39(3): 3000-3011.

Buzacott, J. (1975). Economic order quantities with inflation. *Operational Research Quarterly*: 553-558.

Carter, C. R. and D. S. Rogers (2008). A framework of sustainable supply chain management: moving toward new theory. *International journal of physical distribution & logistics management* 38(5): 360-387.

Çebi, F. and D. Bayraktar (2003). An integrated approach for supplier selection. *Logistics Information Management* 16(6): 395-400.

Çelebi, D. and D. Bayraktar (2008). An integrated neural network and data envelopment analysis for supplier evaluation under incomplete information. *Expert Systems with Applications* 35(4): 1698-1710.

Chai, J., J. N. K. Liu and E. W. T. Ngai (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. *Expert Systems with Applications* 40(10): 3872-3885.

Chan, F. T. S. and N. Kumar (2007). Global supplier development considering risk factors using fuzzy extended AHP-based approach. *Omega* 35(4): 417-431.

Chang, D.-Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research* 95(3): 649-655.

Chen, Y.-J. (2011). Structured methodology for supplier selection and evaluation in a supply chain. *Information Sciences* 181(9): 1651-1670.

Che, Z. H. and H. S. Wang (2010). A hybrid approach for supplier cluster analysis. *Computers & Mathematics with Applications* 59(2): 745-763.

Chen, C. C., M. L. Tseng, Y. H. Lin and Z. S. Lin (2010). Implementation of green supply chain management in uncertainty. *Industrial Engineering and Engineering Management (IEEM), 2010 IEEE International Conference on*,7-10 Dec. 2010.

Chern, M.-S., H.-L. Yang, J.-T. Teng and S. Papachristos (2008). Partial backlogging inventory lot-size models for deteriorating items with fluctuating demand under inflation. *European Journal of Operational Research* 191(1): 127-141.

Chung, K.-J. (2009). An accurate and reliable solution procedure for the EOQ model with deteriorating items under supplier credits linked to the ordering quantity. *Computers & Industrial Engineering* 56(4): 1715-1720.

Commission of the European Communities (2001). Green paper. Promoting a European framework for corporate social responsibility. COM (2001) 366 final. Brussels.

Cornelissen, A. M. G., J. van den Berg, W. J. Koops, M. Grossman and H. M. J. Udo (2001). Assessment of the contribution of sustainability indicators to sustainable development: a novel approach using fuzzy set theory. *Agriculture, Ecosystems & Environment* 86(2): 173-185.

Cruz, J. M. (2011). Modeling the relationship of globalized supply chains and corporate social responsibility. *Journal of Cleaner Production*.

Dai, J. and J. Blackhurst (2011). A four-phase AHP–QFD approach for supplier assessment: a sustainability perspective. *International Journal of Production Research*: 1-17.

Dai, T. and X. Qi (2007). An acquisition policy for a multi-supplier system with a finite-time horizon. *Computers & Operations Research* 34(9): 2758-2773.

De Boer, L., E. Labro and P. Morlacchi (2001). A review of methods supporting supplier selection. *European Journal of Purchasing & Supply Management* 7(2): 75-89.

De, S. K. and A. Goswami (2006). An EOQ model with fuzzy inflation rate and fuzzy deterioration rate when a delay in payment is permissible. *International journal of systems science* 37(5): 323-335.

Dickson, G. W. (1966). An analysis of vendor selection systems and decisions. *Journal of purchasing* 2(1): 5-17.

Ding, H., L. Benyoucef and X. Xie (2005). A simulation optimization methodology for supplier selection problem. *International Journal of Computer Integrated Manufacturing* 18(2-3): 210-224.

Ebrahim, R. M., J. Razmi and H. Haleh (2009). Scatter search algorithm for supplier selection and order lot sizing under multiple price discount environment. *Advances in Engineering Software* 40(9): 766-776.

Elkington, J. Cannibals with Forks: The triple bottom line of 21st Century Business, 1997. *UK: Capstone*.

Friedl, G. and S. M. Wagner (2011). Supplier development or supplier switching? *International Journal of Production Research* 50(11): 3066-3079.

Fu, X., Q. Zhu and J. Sarkis (2012). Evaluating green supplier development programs at a telecommunications systems provider. *International Journal of Production Economics* 140(1): 357-367.

Gál, T., T. Stewart and T. Hanne (1999). *Multicriteria decision making: advances in MCDM models, algorithms, theory, and applications*. Kluwer Academic Pub.

Garfamy, R. M. (2011). Supplier selection and business process improvement: an exploratory multiple case study. *International Journal of Operational Research* 10(2): 240-255.

Gauthier, C. (2005). Measuring Corporate Social and Environmental Performance: The Extended Life-Cycle Assessment. *Journal of Business Ethics* 59(1-2): 199-206.

Genovese, A., S. L. Koh, G. Bruno and P. Bruno (2010). Green supplier selection: A literature review and a critical perspective. *8th International Conference on Supply Chain Management and Information Systems (SCMIS)*, IEEE.

Genovese, A., S. Lenny Koh, G. Bruno and E. Esposito (2013). Greener supplier selection: state of the art and some empirical evidence. *International Journal of Production Research* 51(10): 2868-2886.

Ghodsypour, S. H. and C. O'brien (2001). The total cost of logistics in supplier selection, under conditions of multiple sourcing, multiple criteria and capacity constraint. *International Journal of Production Economics* 73(1): 15-27.

Glock, C. H. (2011). A multiple-vendor single-buyer integrated inventory model with a variable number of vendors. *Computers & Industrial Engineering* 60(1): 173-182.

Govindan, K., R. Khodaverdi and A. Jafarian (2013). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production* 47: 345-354.

Haleh, H. and A. Hamidi (2011). A fuzzy MCDM model for allocating orders to suppliers in a supply chain under uncertainty over a multi-period time horizon. *Expert Systems with Applications* 38(8): 9076-9083.

Hammami, R., Y. Frein and A. B. Hadj-Alouane (2012). An international supplier selection model with inventory and transportation management decisions. *Flexible Services and Manufacturing Journal*: 1-24.

Handfield, R., S. V. Walton, R. Sroufe and S. A. Melnyk (2002). Applying environmental criteria to supplier assessment: A study in the application of the Analytical Hierarchy Process. *European Journal of Operational Research* 141(1): 70-87.

Hassini, E. (2008). Order lot sizing with multiple capacitated suppliers offering leadtime-dependent capacity reservation and unit price discounts. *Production Planning & Control* 19(2): 142-149.

Ho, W., X. Xu and P. K. Dey (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research* 202(1): 16-24.

Hong, J.-D. and J. C. Hayya (1992). Just-in-time purchasing: single or multiple sourcing? *International Journal of Production Economics* 27(2): 175-181.

Hsu, C.-W. and A. H. Hu (2009). Applying hazardous substance management to supplier selection using analytic network process. *Journal of Cleaner Production* 17(2): 255-264.

Hsu, C.-W., T.-C. Kuo, S.-H. Chen and A. H. Hu (2013). Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management. *Journal of Cleaner Production*.

Humphreys, P., A. McCloskey, R. McIvor, L. Maguire and C. Glackin (2006). Employing dynamic fuzzy membership functions to assess environmental performance in the supplier selection process. *International Journal of Production Research* 44(12): 2379-2419.

Humphreys, P., R. McIvor and F. Chan (2003a). Using case-based reasoning to evaluate supplier environmental management performance. *Expert Systems with Applications* 25(2): 141-153.

Humphreys, P. K., Y. K. Wong and F. T. S. Chan (2003b). Integrating environmental criteria into the supplier selection process. *Journal of Materials Processing Technology* 138(1–3): 349-356.

Jang, J., C. Sun and E. Mizutani (1997). Neuro-fuzzy and soft computing. 1997. *PTR Prentice Hall*.

Joshi, S., and M. Gosavi (2011). MEAN VALUE THEOREM. *Bulletin of the Marathwada Mathematical Society*, *12*(1), 55-64.

Kannan, D., R. Khodaverdi, L. Olfat, A. Jafarian and A. Diabat (2013). Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain. *Journal of Cleaner Production*.

Kannan, G., A. N. Haq, P. Sasikumar and S. Arunachalam (2008). Analysis and selection of green suppliers using interpretative structural modelling and analytic hierarchy process. *International Journal of Management and Decision Making* 9(2): 163-182.

Kannan, G., S. Pokharel and P. Sasi Kumar (2009). A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider. *Resources, Conservation and Recycling* 54(1): 28-36.

Karimi, B., S. Fatemi Ghomi and J. Wilson (2003). The capacitated lot sizing problem: a review of models and algorithms. *Omega* 31(5): 365-378.

Keskin, B. B., S. H. Melouk and I. L. Meyer (2010). A simulation-optimization approach for integrated sourcing and inventory decisions. *Computers & Operations Research* 37(9): 1648-1661.

Kilincci, O. and S. A. Onal (2011). Fuzzy AHP approach for supplier selection in a washing machine company. *Expert Systems with Applications* 38(8): 9656-9664.

Kuo, R. J., L. Y. Lee and T.-L. Hu (2010a). Developing a supplier selection system through integrating fuzzy AHP and fuzzy DEA: a case study on an auto lighting system company in Taiwan. *Production Planning & Control* 21(5): 468-484.

Kuo, R. J., Y. C. Wang and F. C. Tien (2010b). Integration of artificial neural network and MADA methods for green supplier selection. *Journal of Cleaner Production* 18(12): 1161-1170.

Laarhoven, P. J. M. v. and W. Pedrycz (1983). A fuzzy extension of Saaty's priority theory. *Fuzzy Sets Syst*. 11(1-3): 199-227.

Lambert, D. M. (2008). *Supply chain management: processes, partnerships, performance*. Supply Chain Management Inst.

Lee, A. H. I., H. Y. Kang, C. F. Hsu and H. C. Hung (2009). A green supplier selection model for high-tech industry. *Expert Systems with Applications* 36(4): 7917-7927.

Lee, T. P. N., A. Genovese and L. S. Koh (2011). Using FAHP to determine the criteria for partner's selection within a green supply chain: the case of hand tool industry in Taiwan. *Journal of Manufacturing Technology Management* 23(1): 25-55.

Liao, C.-N. and H.-P. Kao (2011). An integrated fuzzy TOPSIS and MCGP approach to supplier selection in supply chain management. *Expert Systems with Applications* 38(9): 10803-10811.

Liao, Z. and J. Rittscher (2007). Integration of supplier selection, procurement lot sizing and carrier selection under dynamic demand conditions. *International Journal of Production Economics* 107(2): 502-510.

Lima Junior, F. R., L. Osiro and L. C. R. Carpinetti (2013). A fuzzy inference and categorization approach for supplier selection using compensatory and non-compensatory decision rules. *Applied Soft Computing* 13(10): 4133-4147.

Lin, C.-C. (2004). A weighted max–min model for fuzzy goal programming. *Fuzzy sets and systems* 142(3): 407-420.

Lin, R.-H. (2012). An integrated model for supplier selection under a fuzzy situation. *International Journal of Production Economics* 138(1): 55-61.

Lin, Y.-T., C.-L. Lin, H.-C. Yu and G.-H. Tzeng (2010). A novel hybrid MCDM approach for outsourcing vendor selection: A case study for a semiconductor company in Taiwan. *Expert Systems with Applications* 37(7): 4796-4804.

Linton, J. D., R. Klassen and V. Jayaraman (2007). Sustainable supply chains: An introduction. *Journal of Operations Management* 25(6): 1075-1082.

Lu, L. Y. Y., C. Wu and T. C. Kuo (2007). Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis. *International Journal of Production Research* 45(18-19): 4317-4331.

Mafakheri, F., M. Breton and A. Ghoniem (2011). Supplier selection-order allocation: A two-stage multiple criteria dynamic programming approach. *International Journal of Production Economics*.

Mamdani, E. H. (1974). Application of fuzzy algorithms for control of simple dynamic plant. *Electrical Engineers, Proceedings of the Institution of* 121(12): 1585-1588.

Mihelcic, J. R., J. C. Crittenden, M. J. Small, D. R. Shonnard, D. R. Hokanson, Q. Zhang, H. Chen, S. A. Sorby, V. U. James and J. W. Sutherland (2003). Sustainability science and engineering: the emergence of a new metadiscipline. *Environmental Science & Technology* 37(23): 5314-5324.

Mohammadi, M. and M. M. Tap (2012). A Mixed Integer Programming Model Formulation for Solving the Lot-Sizing Problem. *International Journal of Computer Science Issues* 9(2).

Montazer, G. A., H. Q. Saremi and M. Ramezani (2009). Design a new mixed expert decision aiding system using fuzzy ELECTRE III method for vendor selection. *Expert Systems with Applications* 36(8): 10837-10847.

Neetu and A. K. Tomer (2012). A Deteriorating Inventory Model Under Variable Inflation When Supplier Credits Linked to Order Quantity. *Procedia Engineering* 38(0): 1241-1263.

Ng, W. L. (2008). An efficient and simple model for multiple criteria supplier selection problem. *European Journal of Operational Research* 186(3): 1059-1067.

Onawumi, A.S., OE. Oluleye. and KA. Adebiyi (2011). An Economic Order Quantity Model with Shortages, Price Break and Inflation. *Int. J. Emerg. Sci* 1(3): 465-477.

Önüt, S., S. S. Kara and E. Işik (2009). Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company. *Expert Systems with Applications* 36(2, Part 2): 3887-3895.

Perçin, S. (2006). An application of the integrated AHP-PGP model in supplier selection. *Measuring Business Excellence* 10(4): 34-49.

Pitchipoo, P., P. Venkumar and S. Rajakarunakaran (2013). Fuzzy hybrid decision model for supplier evaluation and selection. *International Journal of Production Research* 51(13): 3903-3919.

Punniyamoorthy, M., P. Mathiyalagan and P. Parthiban (2011). A strategic model using structural equation modeling and fuzzy logic in supplier selection. *Expert Systems with Applications* 38(1): 458-474.

Razmi, J. and H. Rafiei (2010). An integrated analytic network process with mixed-integer non-linear programming to supplier selection and order allocation. *The International Journal of Advanced Manufacturing Technology* 49(9-12): 1195-1208.

Rezaei, J. and M. Davoodi (2006). Genetic algorithm for inventory lot-sizing with supplier selection under fuzzy demand and costs. *Advances in Applied Artificial Intelligence*: 1100-1110.

Rezaei, J. and M. Davoodi (2008). A deterministic, multi-item inventory model with supplier selection and imperfect quality. *Applied Mathematical Modelling* 32(10): 2106-2116.

Rezaei, J. and M. Davoodi (2011a). A joint pricing, lot-sizing, and supplier selection model. *International Journal of Production Research* 50(16): 4524-4542.

Rezaei, J. and M. Davoodi (2011b). Multi-objective models for lot-sizing with supplier selection. *International Journal of Production Economics* 130(1): 77-86.

Rezaei, J. and N. Salimi (2012). Economic order quantity and purchasing price for items with imperfect quality when inspection shifts from buyer to supplier. *International Journal of Production Economics* 137(1): 11-18.

Robinson, P., A. Narayanan and F. Sahin (2009). Coordinated deterministic dynamic demand lot-sizing problem: A review of models and algorithms. *Omega* 37(1): 3-15.

Sadeghi Moghadam, M. R., A. Afsar and B. Sohrabi (2008). Inventory lot-sizing with supplier selection using hybrid intelligent algorithm. *Applied Soft Computing* 8(4): 1523-1529.

Sadeghieh, A., M. Dehghanbaghi, A. Dabbaghi and S. Barak (2011). A genetic algorithm based grey goal programming (G3) approach for parts supplier evaluation and selection. *International Journal of Production Research* 50(16): 4612-4630.

Sana, S. S. (2008). An EOQ model with a varying demand followed by advertising expenditure and selling price under permissible delay in payments: for a retailer. *International Journal of Modelling, Identification and Control* 5(2): 166-172.

Sana, S. S. and K. S. Chaudhuri (2008). A deterministic EOQ model with delays in payments and price-discount offers. *European Journal of Operational Research* 184(2): 509-533.

Sawik, T. (2011). Selection of a dynamic supply portfolio in make-to-order environment withrisks. *Computers & Operations Research* 38(4): 782-796.

Seuring, S. and M. Müller (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production* 16(15): 1699-1710.

Shaik, M. and W. Abdul-Kader (2011). Green supplier selection generic framework: a multi-attribute utility theory approach. *International Journal of Sustainable Engineering* 4(01): 37-56.

Shaw, K., R. Shankar, S. S. Yadav and L. S. Thakur (2012). Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Systems with Applications* 39(9): 8182-8192.

Shen, L., L. Olfat, K. Govindan, R. Khodaverdi and A. Diabat (2012). A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences. *Resources, Conservation and Recycling*.

Sucky, E. (2007). A model for dynamic strategic vendor selection. *Computers & Operations Research* 34(12): 3638-3651.

Teuteberg, F. and D. Wittstruck (2010). A Systematic Review of Sustainable Supply Chain Management Research. *Accounting And Information Systems University Of Osnabriick*.

Tiwari, R., S. Dharmar and J. Rao (1987). Fuzzy goal programming—an additive model. *Fuzzy sets and systems* 24(1): 27-34.

Tseng, M.-L., J. H. Chiang and L. W. Lan (2009). Selection of optimal supplier in supply chain management strategy with analytic network process and choquet integral. *Computers & Industrial Engineering* 57(1): 330-340.

Tsai, W. H. and S.-J. Hung (2009a). A fuzzy goal programming approach for green supply chain optimisation under activity-based costing and performance evaluation with a value-chain structure. *International Journal of Production Research* 47(18): 4991-5017.

Tsai, W. H. and S.-J. Hung (2009b). Treatment and recycling system optimisation with activity-based costing in WEEE reverse logistics management: an environmental supply chain perspective. *International Journal of Production Research* 47(19): 5391-5420.

Ustun, O. and E. A. Demirtas (2008). Multi-period lot-sizing with supplier selection using achievement scalarizing functions. *Computers & Industrial Engineering* 54(4): 918-931.

Wagner, H.M. (2004). Comments on ‘‘Dynamic Version of the Economic Lot Size Model’’. *Management Science* 50 (12): 1775–1777.

Wagner, H. M. and T. M. Whitin (1958). Dynamic version of the economic lot size model. *Management science*: 89-96.

Weber, C. A., J. R. Current and W. C. Benton (1991). Vendor selection criteria and methods. *European Journal of Operational Research* 50(1): 2-18.

Wittstruck, D. and F. Teuteberg (2012). Integrating the concept of sustainability into the partner selection process: a fuzzy–AHP–TOPSIS approach. *International Journal of Logistics Systems and Management* 12(2): 195-226.

Woarawichai, C., T. Kullpattaranirun and V. Rungreunganun (2011). Inventory Lot-Sizing Problem with Supplier Selection under Storage Space and Budget Constraints. *International Journal of Computer Science* 8.

Wu, C., D. Barnes, D. Rosenberg and X. Luo (2009). An analytic network process-mixed integer multi-objective programming model for partner selection in agile supply chains. *Production Planning & Control* 20(3): 254-275.

Wu, T. and J. Blackhurst (2009). Supplier evaluation and selection: an augmented DEA approach. *International Journal of Production Research* 47(16): 4593-4608.

Yang, H.-L. (2004). Two-warehouse inventory models for deteriorating items with shortages under inflation. *European Journal of Operational Research* 157(2): 344-356.

Yang, H.-L. (2006). Two-warehouse partial backlogging inventory models for deteriorating items under inflation. *International Journal of Production Economics* 103(1): 362-370.

Yang, H.-L., J.-T. Teng and M.-S. Chern (2010). An inventory model under inflation for deteriorating items with stock-dependent consumption rate and partial backlogging shortages. *International Journal of Production Economics* 123(1): 8-19.

Yeh, W.-C. and M.-C. Chuang (2011). Using multi-objective genetic algorithm for partner selection in green supply chain problems. *Expert Systems with Applications* 38(4): 4244-4253.

Zadeh, L. A. (1965). Fuzzy sets. *Information and control* 8(3): 338-353.

Zailani, S., K. Jeyaraman, G. Vengadasan and R. Premkumar (2012). Sustainable supply chain management (SSCM) in Malaysia: A survey. *International Journal of Production Economics*.

Zeleny, M. and J. L. Cochrane (1982). *Multiple criteria decision making*. McGraw-Hill New York.

Zeydan, M., C. Çolpan and C. Çobanoğlu (2011). A combined methodology for supplier selection and performance evaluation. *Expert Systems with Applications* 38(3): 2741-2751.

Zhang, Y., F. Tao, Y. Laili, B. Hou, L. Lv and L. Zhang (2013). Green partner selection in virtual enterprise based on Pareto genetic algorithms. *The International Journal of Advanced Manufacturing Technology*: 1-17.

Zimmermann, H.-J. (1978). Fuzzy programming and linear programming with several objective functions. *Fuzzy sets and systems* 1(1): 45-55.